GENIUS-TF: a test facility for the GENIUS project

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GENIUS is a proposal for a large scale detector of rare events. As a first step of the experiment, a small test version, the GENIUS test facility, will be build up at the Laboratorio Nazionale del Gran Sasso (LNGS). With about 40 kg of natural Ge detectors operated in liquid nitrogen, GENIUS-TF could exclude (or directly confirm) the DAMA annual modulation signature within about two years of measurement.

1 Introduction

GENIUS (GErmanium in liquid NItrogen Underground Setup) is a proposal for operating a large amount of 'naked' Ge detectors in liquid nitrogen to search for rare events such as WIMP-nucleus scattering, neutrinoless double beta decay and solar neutrino interactions, with a much increased sensitivity relative to existing experiments [1–3]. By removing (almost) all materials from the immediate vicinity of the Ge-crystals, their absolute background can be considerably decreased with respect to conventionally operated detectors. The liquid nitrogen acts both as a cooling medium and as a shield against external radioactivity. The proposed scale of the experiment is a nitrogen tank of about 12 m diameter and 12 m height with 100 kg of natural Ge and 1 ton of enriched ^{76}Ge in the dark matter and double beta decay versions, respectively, suspended in its center.

To cover large parts of the MSSM parameter space, relevant for the detection of neutralinos as dark matter candidates [4–6], a maximum background level of 10^{-2} counts/(kg y keV) in the energy region below 50 keV has to be achieved. In the double beta decay region (Q-value = 2038.56 keV) a background of 0.3 events/(t y keV) is needed in order to test the effective Majorana neutrino mass down to 0.01 eV (90%C.L.). This implies a very large background reduction in comparison to our recent best results [7,8] with the Heidelberg–Moscow experiment.

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The focus of this paper is to present a small scale version experiment, the GENIUS test facility (GENIUS-TF), which will be built up at the Laboratorio Nazionale del Gran Sasso (LNGS). It is designed to test experimentally the feasibility of GENIUS. Up to 40 kg of Ge detectors will be operated directly in liquid nitrogen, the overall dimension of the experiment not exceeding $2\,\mathrm{m}\times2\,\mathrm{m}\times2\,\mathrm{m}$. As a side effect, it will improve limits on WIMP-nucleon cross sections with respect to our results with the Heidelberg–Moscow and HDMS experiments [7,9]. The relatively large mass of Ge compared to existing experiments would permit to search directly for a WIMP signature in form of the predicted [10] seasonal modulation of the event rate.

2 The GENIUS Test Facility

GENIUS-TF consists of up to 14 natural Ge crystals (40 kg) operated in a volume of $0.064\,\mathrm{m}^3$ of ultra-pure liquid nitrogen. The liquid nitrogen is housed by a 0.5 mm thick steel vessel inside a $0.9\,\mathrm{m}\times0.9\,\mathrm{m}\times0.9\,\mathrm{m}$ box of polystyrene foam, with a 5 cm thick inner shield of high purity Ge bricks (the basic concept is described in [11]). Outside the foam box there are 10 cm of low-level copper, 30 cm of lead and 15 cm of borated polyethylene as shields against the natural radioactivity of the environment (see Fig. 1). The Ge crystals are positioned in two layers (each layer of 7 detectors in two concentric circles) on a holder system made of high molecular polyethylene. The signal and high voltage contacts of the individual crystals are established using a minimized amount of ultra pure stainless steel (about 3 g) as already demonstrated in previous experiments [2,12,13].

3 Background considerations

The aim of GENIUS-TF is to reach the background level of 2 events/(kg y keV) in the energy region below 50 keV (50 keV ionization energy in germanium corresponds to about 200 keV nuclear recoil energy). This is one order of magnitude lower than the actual background of the Heidelberg-Moscow experiment and two orders of magnitude higher than the final goal of GENIUS. To estimate the background contributions from the various components we performed detailed Monte Carlo simulations of the relevant background sources using the geometry shown in Fig. 1 [1]. The simulations are based on the GEANT3.21 package [14] extended for nuclear decays.

[1] in [11] some first simulations with one detector in a simplified geometry had been made

The sources of background can be divided into external and internal ones. The external background is generated by events originating from outside the shields, such as photons and neutrons from the Gran Sasso rock and by muon interactions. We simulated the measured photon [16], neutron [17] and muon [18] fluxes at LNGS. With a total of 30 cm of lead and 15 cm of borated polyethylene shield, the contribution of the photons and neutrons are negligible. The muons yield a count rate of 2×10^{-2} events/(kg y keV) in the energy region 0-50 keV (this, and all following rates are given after computing the anti-coincidence between the 14 Ge detectors). Secondary neutron induced interactions in the liquid nitrogen, as well as negative muon capture and inelastic muon scattering reactions generate only a negligible contribution to the overall expected background rate (for details see [2,3,12]).

Internal background arises from residual impurities in the liquid nitrogen, the steel vessel, the polystyrene foam isolation, the Ge and Cu shields, the crystal holder system, the Ge crystals themselves and from activation of the Ge crystals and of the copper during fabrication and transportation at the Earths surface. The assumed intrinsic impurity levels for the simulated materials and the resulting count rates in the low-energy region are listed in Table 1.

The values assumed for the ^{238}U and ^{232}Th contamination of the liquid nitrogen are 1000 times higher than already measured by BOREXINO [19] for their liquid scintillator. The ^{222}Rn contamination of freshly produced liquid nitrogen was recently measured to be 325 μBq/m^3 [21]. No additional assumptions were made. The U/Th, ^{40}K and ^{60}Co contamination for the steel are taken from a recent measurement in the Heidelberg low level lab [20]. The intrinsic impurity levels in Ge crystals are conservative upper limits from measurements with the detectors of the Heidelberg–Moscow experiment. We assumed a 100 times higher contamination level for the HPGe bricks used as inner shield. The contamination level of polystyrene was measured with a natural Ge detector in appropriate shielding at LNGS [13]. However, no material selection or special handling were applied and a higher purity can certainly be reached. The ^{238}U, ^{232}Th and ^{40}K contamination values, as well as the cosmogenic activation of the Cu shield were taken from a former measurement with the Ge detectors of the Heidelberg-Moscow experiment [15]. In the Heidelberg-Moscow experiment we also measure activities of the anthropogenic isotopes ^{125}Sb, ^{207}Bi, ^{134}Cs, ^{137}Cs. Although these impurities could be found anywhere in the experimental setup, we assume that they are located in the copper shield. The respective activities are taken from [22]. The assumed values for polyethylene were reached by the SNO experiment [23] for an acrylic material. Though a 10-100 times higher contamination level would also be acceptable, such a crystal support system still has to be developed.

We have estimated the cosmogenic production rates of radioisotopes in the Ge–crystals with the Σ program [24]. Assuming an unshielded production and transportation time of 30 days at sea level for the Ge–detectors, and a deactivation time of one year, we obtain the radioisotope concentrations listed in Table 2 (for ^{68}Ge the saturation activity is assumed; the value for ^{3}H is taken from [25]). All other produced radionuclides have much smaller activities due to their shorter half lives. The count rate between 5 keV and 11 keV is dominated by X–rays from the decays of the various isotopes (see Table 2). However, if the energy threshold of the Ge detectors will be as low as 0.7 keV (as stated by the manufacturer) GENIUS-TF will nonetheless be sensitive to low WIMP masses. The sum of all contributions from the cosmogenic activation of the Ge crystals amounts to 4×10^{-1} counts/(kg y keV) between 1 and 4 keV and between 11 and 50 keV. After the decay of those isotopes with half lives around 1 year, this region will be dominated by contribution from ^{3}H and ^{63}Ni, due to their low Q–value (18.6 keV and 66.95 keV) and large half life (12.33 yr and 100.1 yr). Figure 2 shows the sum and the single contributions from the different isotopes.

Summing up the background contributions discussed so far, the mean count rate in the low energy region amounts to about 4 events/(kg y keV). In Fig. 3 the spectra of individual contributions and the summed up total background spectrum are shown (after one year of storage of the Ge detectors below ground). The low-energy spectrum is dominated by events originating from the polystyrene foam isolations, from the copper shield and the steel vessel. Regarding the polystyrene, no material selections were performed so far and efforts in this direction are starting to being made. Careful selections will have to be performed also for the steel vessel, which, in spite of its low total mass, yields a significant contribution due to its proximity to the Ge crystals. Lower contamination values by a factor of 5-10 than assumed in this simulation were already reached in the past [20]. For copper the cosmogenic activities of ^{54}Mn, ^{57}Co, ^{58}Co, ^{60}Co, as well as anthropogenic activities are dominating and low exposures at the Earths surface as well as electro-polishing of surfaces are desirable.

4 Goals of GENIUS-TF

The primary goal of GENIUS-TF is to demonstrate the feasibility of the GENIUS project. It has to be shown that 'naked' Ge detectors work reliably in liquid nitrogen over a longer period of time (at least for one year). Material selections have to be performed for various experimental components and their purity tested down to 1 event/(kg y keV). A crystal support system, made of low-radioactivity polyethylene has to be developed and designed such that it can be extended in order to house up to 40 crystals (100 kg). A new, modular data acquisition system and electronics have to be developed and tested. Besides above issues, which certainly are important, GENIUS-TF can have a physics program of its own.

WIMP Dark Matter

With 40 kg of natural Ge and a background of 2 events/(kg y keV) in the energy region below 50 keV, GENIUS-TF can cover the 'evidence region' in the MSSM parameter space for neutralinos as dark matter candidates singled out by the DAMA experiment [26]. It would exclude DAMA after about one year of measurement, delivering an independent test by using a different technology and raw data without background subtraction.

Figure 5 shows a comparison of existing constraints and future sensitivities of cold dark matter experiments, together with the theoretical expectations for neutralino scattering rates [27]. For GENIUS-TF, energy thresholds of 2 keV and 11 keV (worst case scenario) were assumed. In addition to setting limits on WIMP-nucleon cross sections, GENIUS-TF will be able to test the DAMA region by directly looking for a seasonal modulation of the event rate and of the energy spectrum. Depending on the background and energy threshold, an overall exposure between 1 and 5 years are needed in order to test the DAMA region with 99.5% C.L. (according to [28]). For example, for an energy threshold of 2 keV and a background level of 4 events/(kg y keV), 1.4 yr of measurement with 40 kg of Ge are required. Even for an initial lower mass of 20 kg the time scale of about 3 yr would still be acceptable.

Neutrinoless Double Beta Decay

Neutrinoless double beta decay provides a unique method for gaining information about the absolute neutrino mass scale and of discerning between a Majorana and a Dirac neutrino. The current most stringent experimental limit on the effective Majorana neutrino mass, $\langle \mathrm{m} \rangle$ <0.35 eV, comes from the Heidelberg-Moscow experiment [29]. For a significant step beyond this limit, much higher source strengths and lower background levels are needed, a goal which could be accomplished by the GENIUS experiment operating 300–400 detectors made of enriched ^{76}Ge (1 ton).

Operating the enriched ^{76}Ge detectors of the Heidelberg-Moscow experiment within the GENIUS test facility could improve existing half life limits by up to a factor of 8. The Heidelberg-Moscow Ge detectors have the advantage of having been stored for several years at LNGS, so that cosmogenic activities will not play a major role for the background. However, in order to improve the background in the high-energy region by a factor of 30, more stringent requirements for the purity of the used materials have to be made (see Table 3).

The U/Th contamination of nitrogen is 100 times less stringent than measured by BOREXINO, the contamination of the Ge bricks 10 times higher than the upper limit for the detectors of the Heidelberg-Moscow experiment. For steel, the best measured values so far (^{238}U: 0.6 mBq/kg, ^{232}Th: 0.2 mBq/kg [20]) have been assumed. While the above components are not critical, the background is dominated by the U/Th contaminations of the polystyrene foam and of the copper shield. Here 50 and 10 times lower contamination levels than measured so far have been assumed. While for polystyrene such values could be achieved after severe material selections, the case of copper is more subtle and it might have to be replaced by a cleaner material, as for example low-level lead. The muon contribution, which amounts to about 1×10^{-3}events/kg yr keV could be further reduced by a factor 10 with a muon veto with 90% efficiency. Fig. 4 shows the individual contributions and the sum spectrum from 2000 to 2080 keV. The background of 6×10^{-3}events/kg yr keV is about a factor of 30 lower than the (raw) background of the Heidelberg-Moscow experiment in the energy region between 2000-2080 keV [12] and can be further reduced by a factor of 3 with pulse shape analysis [8]. It would allow to reach a half life limit of about 1.6×10^{26} yr and thus to test the effective Majorana neutrino mass down to 0.1 eV with 90% C.L. after 6 years of measurement. Although 6 years seem long, the time scale is short compared to those of other experiments proposed to improve the Heidelberg-Moscow mass limit by a significant amount, such as GENIUS [3], EXO [34] or CUORE [35].

5 Summary and Outlook

We have presented a test facility for the GENIUS experiment, GENIUS-TF, which is approved and is going to be installed at LNGS in the course of the year 2001. We have estimated the expected background from the various experimental components in a detailed Monte Carlo simulation based on GEANT3.21. A background reduction by a factor of 10 compared to the Heidelberg-Moscow experiment [7] seems feasible even with 30 days exposure of the Ge crystals at the Earths surface. The dominating sources of background arise from the U/Th contamination of the polystyrene foam isolation, from the steel vessel and from the cosmogenic activation and anthropogenic contamination of the copper shield. While for polystyrene and steel material selections will be pursued, low exposure times and special treatment of the copper surfaces will be essential.

Besides offering an environment to test different solutions to be adopted in the GENIUS experiment, GENIUS-TF will bring its own contribution to the fields of direct WIMP detections and neutrinoless double beta decay search. It will allow to improve current limits on WIMP-nucleon cross sections and thus to test the DAMA evidence region [26] within about one year of measurement.

Moreover, with 40 kg of WIMP target material and an energy threshold of 1 keV (11 keV in the worst case), an eventual WIMP signature could be seen (or excluded) directly within 1 year (5 years) of measurement. No other planned experiment for the near future and using a different technique than DAMA can achieve this goal. The operation of the Heidelberg-Moscow enriched ^{76}Ge detectors (about 11 kg of active mass) in the same facility would allow to test the effective Majorana neutrino mass down to 0.1 eV with 90% C.L. within 6 years of measurement.

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References

[1] H.V. Klapdor–Kleingrothaus: In *Proc. of Beyond the Desert 1997*, ed. by H.V. Klapdor–Kleingrothaus, H. Päs (IOP Bristol 1998) pp. 485–531, H.V. Klapdor–Kleingrothaus, Int. Journ. Mod. Phys. A **13**, 3953 (1998), H.V. Klapdor-Kleingrothaus, M. Hirsch, Z. Phys. A **359**, 351 (1997), H.V. Klapdor-Kleingrothaus, J. Hellmig, M. Hirsch, J. Phys. G **24**, 438 (1998).

[2] L. Baudis, G. Heusser, B. Majorovits, Y. Ramachers, H. Strecker, H.V. Klapdor-Kleingrothaus, Nucl. Instr. Meth. A 426, 425 (1999).

[3] H.V. Klapdor-Kleingrothaus, L. Baudis, G. Heusser, B. Majorovits, H. Päs, 'GENIUS: a Supersensitive Germanium Detector System for Rare Events', Proposal, MPI-H-V26-1999, hep-ph/9910205 (1999).

[4] G. Jungman, M. Kamionkowski, K. Griest, Phys. Rep. 267, 195 (1996).

[5] V. Bednyakov, H.V. Klapdor-Kleingrothaus, S. Kovalenko, Y. Ramachers, Z. Phys. A 357, 339 (1997).

[6] V. Bednyakov, H.V. Klapdor-Kleingrothaus, submitted to Phys. Rev. D, (2000).

[7] L. Baudis et al. (Heidelberg–Moscow collaboration), Phys. Rev. D 59, 022001 (1998).

[8] L. Baudis et al. (Heidelberg–Moscow collaboration), Phys. Rev. Lett. 83, 41 (1999).

[9] L. Baudis, A. Dietz, B. Majorovits, F. Schwamm, H. Strecker, H. V. Klapdor-Kleingrothaus, Phys. Rev. D 63, 22001 (2001), astro-ph/0008339.

[10] K. Freese, J. Frieman, and A. Gould, Phys. Rev. D 37 3388 (1988).

[11] B. Majorovits, L. Baudis, G. Heusser, H. Strecker, H. V. Klapdor-Kleingrothaus, Nucl. Instr. Meth. A 455, 371 (2000).

[12] L. Baudis, PhD Thesis, University of Heidelberg (1999).

[13] B. Majorovits, PhD Thesis, University of Heidelberg (2000).

[14] GEANT3.21: Detector Description and Simulation Tool, Geneva (1993).

[15] M. Günther et al. (Heidelberg–Moscow Collaboration), Phys. Rev. D 55, 54 (1997).

[16] C. Arpesella, Nucl. Phys. (Proc. Suppl.) A 28, 420 (1992).

[17] P. Belli et al., Nuovo Cim. A 101, 959 (1989).

[18] deMarzo (MACRO collaboration), Nucl. Instr. Meth. A 314, 380 (1992).

[19] G. Alimonti et al. (BOREXINO Collaboration), Astropart. Phys. 8, 141 (1998).

[20] G. Heusser, private communication.

[21] G. Heusser et al., Appl. Rad. Inst. 52, 691 (2000).

[22] B. Maier, PhD Thesis, University of Heidelberg (1995).

[23] SNO Collaboration: In *Proceedings of the 4th International Solar Neutrino Conference, Heidelberg, April 8-11, 1997*, ed. by W. Hampel (1997) pp. 210.

[24] J. Bockholt, PhD Thesis, University of Heidelberg (1994).

[25] Avignone III et. al, Nucl. Phys. B (Proc. Suppl) 28 A 280 (1992).

[26] R. Bernabei et al., Phys. Lett. B 424, 195 (1998), Phys. Lett. B 450, 448 (1999), Phys. Lett. B 480, 23 (2000).

[27] V.A. Bednyakov, H.V. Klapdor-Kleingrothaus: 'SUSY Spectrum Constraints on Direct Dark Matter Detection', Phys. Rev. D (2000) accepted, hep-ph/9908427.

[28] S. Cebrian et al., Astropart.Phys. 14 339-350 (2001), hep-ph/9912394.

[29] A. Dietz, L. Baudis, G. Heusser, H.V. Klapdor-Kleingrothaus, I.V. Krivosheina, S. Kolb, B. Majorovits, H. Päs, H. Strecker, V. Alexeev, A. Balysh, A. Bakalyarov, S.T. Belyaev, V.I. Lebedev, and S. Zhukov in Proc. of the Third Int. Conference on Dark Matter in Astro– and Particle Physics (DARK2000) July 2000, Heidelberg, Eds. H.V. Klapdor–Kleingrothaus and B. Majorovits, IOP, Bristol& Philadelphia, 2001.

[30] R. Bernabei et al., Nucl. Phys. B 70 (Proc. Suppl), 79 (1998).

[31] R. Abusaidi et al. (CDMS Collaboration), Nucl. Instrum. Meth. A 444, 345 (2000), Phys. Rev. Lett. 84 5699-5703 (2000).

[32] M. Bravin et al.: Astrop. Physics 12, 107 (1999).

[33] R.W. Schnee et al.: Physics Reports 307 (Proc. Suppl.), 283 (1998).

[34] M. Danilov et al., Phys.Lett. B 480, 12 (2000).

[35] E. Previtali et al., in Proc. of the Second Int. Conference on Dark Matter in Astro– and Particle Physics (DARK98) July 1998, Heidelberg, Eds. H.V. Klapdor–Kleingrothaus and L. Baudis, IOP, Bristol& Philadelphia, 1999.

Table 1
Assumed intrinsic impurity levels and resulting count rates for the simulated background components in the energy region relevant for dark matter detection.

Source	Radionuclide	Purity	Count rate (0-50 keV) [events/(kg y keV)]
Ge crystals	^{238}U	1.8×10^{-15}g/g	1.2×10^{-3}
	^{232}Th	5.7×10^{-15}g/g	0.5×10^{-3}
Holder system	U/Th, K	1×10^{-12}, 1×10^{-9}g/g	1×10^{-2}
Nitrogen	^{238}U	3.5×10^{-13}g/g	3×10^{-2}
	^{232}Th	4.4×10^{-13}g/g	2×10^{-2}
	^{40}K	1×10^{-11}g/g	3×10^{-3}
	^{222}Rn	325 μBq/m^3	4×10^{-3}
Steel	^{238}U	3 mBq/kg	3×10^{-1}
	^{232}Th	4 mBq/kg	4.5×10^{-1}
	^{40}K	2 mBq/kg	1.5×10^{-2}
	^{60}Co	2 mBq/kg	3×10^{-1}
Ge shield	^{238}U	1.8×10^{-13}g/g	4.5×10^{-2}
	^{232}Th	5.7×10^{-13}g/g	6×10^{-2}
	^{40}K	1×10^{-11}g/g	4.5×10^{-4}
Polystyrene shield	^{238}U	1.7×10^{-10}g/g	1.5×10^{-1}
	^{232}Th	1.8×10^{-9}g/g	6×10^{-1}
	^{40}K	2.6×10^{-7}g/g	4×10^{-2}
Cu shield	^{238}U	5.4×10^{-12}g/g	2.5×10^{-1}
	^{232}Th	3.0×10^{-12}g/g	6.5×10^{-2}
	^{40}K	4.5×10^{-10}g/g	6×10^{-3}
cosmogenics	^{54}Mn, ^{57}Co, ^{58}Co, ^{60}Co	23,30,50,70 μBq/kg	8×10^{-1}
anthropogenics	^{125}Sb, ^{207}Bi, ^{134}Cs, ^{137}Cs	50,8,150,11 μBq/kg	7.5×10^{-1}

Table 2
Cosmogenically produced isotopes in the Ge crystals for an exposure at sea level of 30 days and a subsequent deep underground storage of 1 year (for ^{68}Ge the saturation activity was assumed)

Isotope	Decay, $T_{1/2}$	Energy deposition in the crystal [keV]	A [μBq kg^{-1}]
^{3}H	β^-, 12.33 yr	E_{β^-}= 18.6 keV	0.12
^{49}V	EC, 330 d	E_K(Ti)= 5, no γ	2.4
^{54}Mn	EC+β^+, 312.3 d	E_γ= 840.8, E_K(Cr)= 5.4	3.1
^{55}Fe	EC, 2.73 yr	E_K(Mn)= 6, no γ	1.6
^{57}Co	EC, 271.8 d	E_γ= 20.81,142.8, E_K(Fe)= 6.4	3.5
^{58}Co	EC+β^+, 70.9 d	E_γ= 817.2, E_K(Fe)= 6.4	1.5
^{60}Co	β^-, 5.27 yr	E_{β^-}= 318, E_γ=1173.2,1332.5	0.7
^{63}Ni	β^-, 100.1 yr	E_{β^-}= 66.95, no γ	0.04
^{65}Zn	EC+β^+, 244.3 d	E_γ=1124.4, E_K(Cu)=8-9	27
^{68}Ge	EC, 270.8 d	E_K(Ga)=10.37	676
^{68}Ga	EC+β^+, 67.6 m	Q-value=2921.1	676

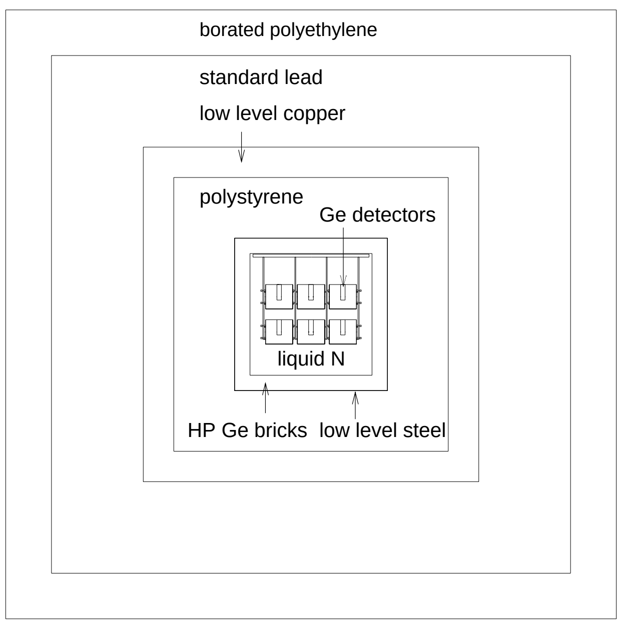

Fig. 1. Schematic view of the GENIUS test facility. 14 HPGe detectors are operated in a steel vessel filled with liquid nitrogen, with an inner shield of HPGe bricks, isolated by polystyrene and surrounded by copper, lead and borated polyethylene shields.

Table 3
Assumed intrinsic impurity levels and resulting count rates for the simulated background components in the energy region relevant for neutrinoless double beta decay in ^{76}Ge.

Source	Radionuclide	Purity	Count rate (2000-2080 keV) [events/(kg y keV)]
Ge crystals	^{238}U	1.8×10^{-15} g/g	2×10^{-5}
	^{232}Th	5.7×10^{-15} g/g	1×10^{-5}
Holder system	U/Th	1×10^{-12}	1×10^{-5}
Nitrogen	^{238}U	3.5×10^{-14} g/g	7×10^{-5}
	^{232}Th	4.4×10^{-14} g/g	4×10^{-5}
	^{222}Rn	325 μBq/m^3	6×10^{-5}
Steel	^{238}U	0.6 mBq/kg	6×10^{-4}
	^{232}Th	0.2 mBq/kg	8×10^{-4}
	^{60}Co	2 mBq/kg	1×10^{-5}
Ge shield	^{238}U	1.8×10^{-14} g/g	4×10^{-5}
	^{232}Th	5.7×10^{-14} g/g	2×10^{-4}
Polystyrene shield	^{238}U	3.4×10^{-12} g/g	5×10^{-5}
	^{232}Th	3.6×10^{-11} g/g	6×10^{-4}
Cu shield	^{238}U	5.4×10^{-13} g/g	4×10^{-4}
	^{232}Th	3.0×10^{-13} g/g	4×10^{-4}

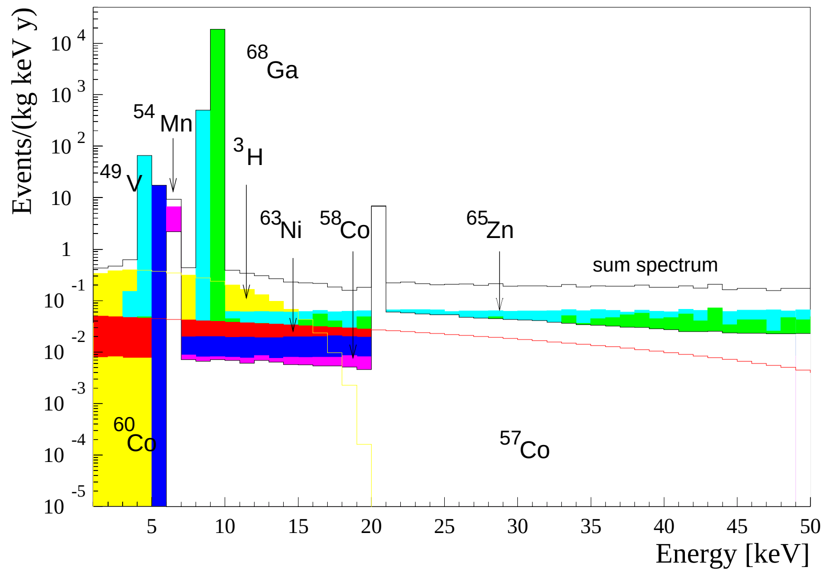

Fig. 2. Background originating from cosmic activation of the Ge crystals at sea level with 30 days exposure and 1 year deactivation below ground.

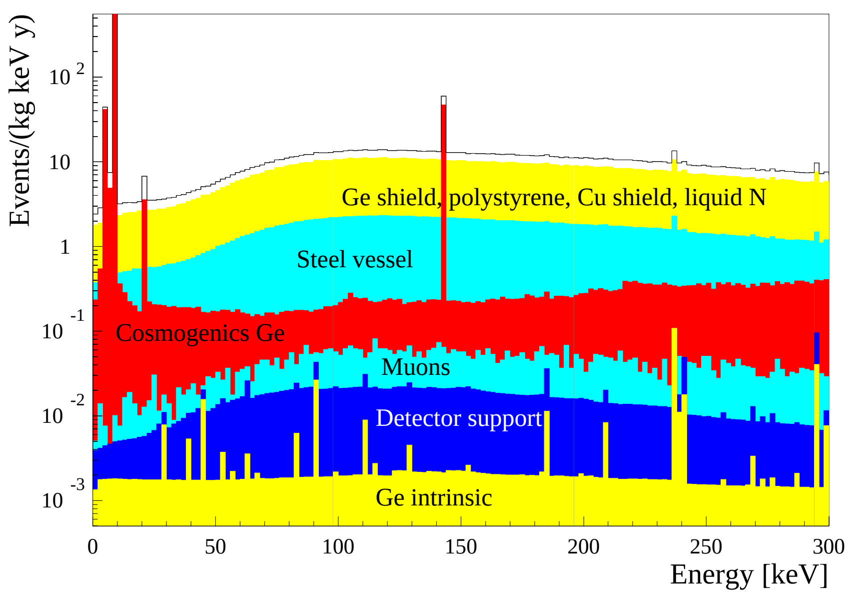

Fig. 3. Simulated spectra of the dominant background sources for the GENIUS test facility. One year of storage below ground for the Ge detectors was assumed. Shown is the low-energy region with contributions from the germanium and copper shields, the polystyrene isolation and the detector support system, the liquid nitrogen, cosmogenic activation of the Ge crystals and intrinsic impurities of the crystals and muon induced background. The solid line represents the sum spectrum of all the simulated components.

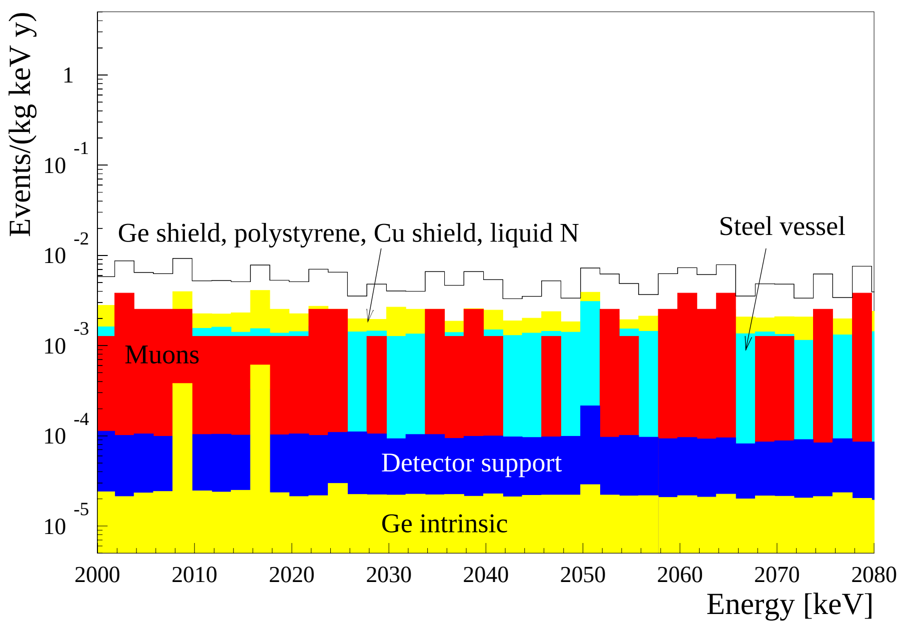

Fig. 4. Simulated spectra of the dominant background sources for the enriched ^{76}Ge detectors of the Heidelberg-Moscow experiment in the GENIUS-TF setup. The energy region relevant for the search of the neutrinoless double beta decay is shown. The solid line represents the sum spectrum of all the simulated components.

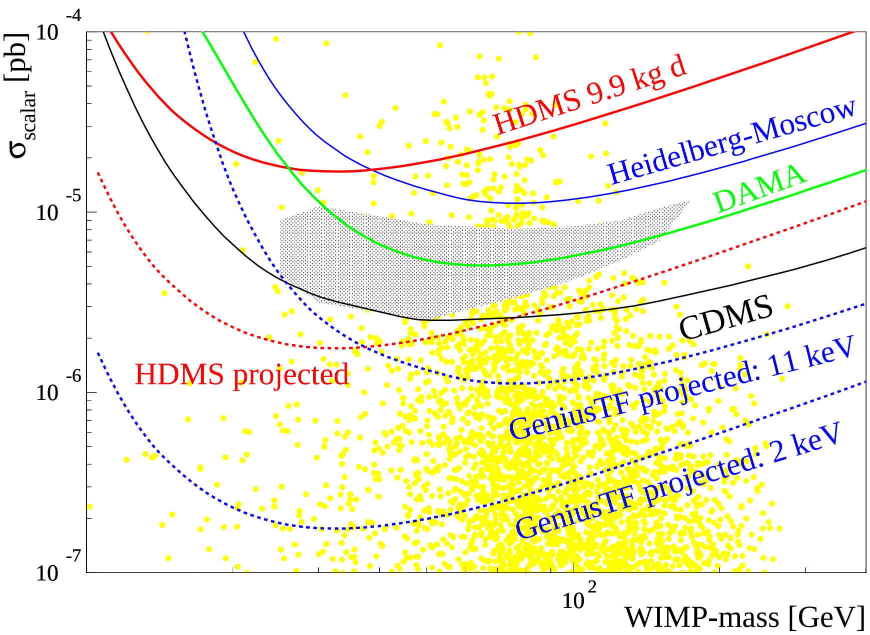

Fig. 5. WIMP-nucleon cross section limits as a function of the WIMP mass for spin-independent interactions. The solid lines are current limits of the Heidelberg-Moscow experiment [7], the HDMS prototype [9], the DAMA experiment [30] and the CDMS experiment [31]. The dashed curves are the expectation for HDMS [9] and for GENIUS-TF with an energy threshold of 11 keV and 2 keV respectively, and a background index of 2 events/kg y keV below 50 keV. The filled contour represents the 2σ evidence region of the DAMA experiment [26]. The experimental limits are compared to expectations (scatter plot) for WIMP-neutralinos calculated in the MSSM parameter space at the weak scale under the assumption that all superpartner masses are lower than 300 GeV - 400 GeV [27].